Abstract for the general public

Currently, one thousand million people suffer from neurological issues, such as epilepsy, Alzheimer's and Parkinson's diseases, migraines, sclerosis, or neural infections. In most cases, restoration of the neural path can be done by the introduction of electrodes within the neural tissue. Placing the electrode in the neural environment results in the spontaneous formation of the interface between neural tissue and the surface of the electrode. Because signals transmission in the nervous system depends on the electrical carrier (ions) and chemical carrier (neurotransmitters), monitoring/stimulating the nervous system by the electrode can be obtained through the electrical and chemical interface. To ensure effective stimulating and/or recording by the electrode during the implantation, the electrical interface electrode material should be characterized with low interfacial impedance, high electrical stability, high charge injection capacity, and high electroactivity, while chemical interface should be additionally tailored with anti-inflammatory drug reservoir to decrease inflammation after the implantation process. Nowadays, the market of neural electrodes is mainly based on pure metals such as gold or platinum. The metals reveal plane rigid structure, which integrates poorly with the tissue environment, causing high inflammation. This, in turn, leads to degeneration of signal transmission and the effective lifetime of the electrode becomes limited. Modulation of the interfacing electrode by nanostructured material such as conducting polymer coating has recently become an attractive option for providing efficient signal transmission for neural application. Recently, there is also a trend toward miniaturization and a shift from rigid to flexible substrate and materials for electronic systems/devices. The same could be observed in the case of electrodes for neural application i.e.: a new, more elastic form of conducting polymer poly(3,4-ethylenedioxythiophene) (PEDOT) i.e. hydrogel or flexible electrode substrate have been proposed. Indeed, the elastic form of the electrode reveals mechanical properties similar to the neural tissue, however, it is not known whether the hydrogel form of the polymer or flexible electrode substrate still provides effective electrical interface parameters toward neural stimulation. Moreover, the proposed electrodes stimulate/monitor the nervous system only through the electrical interface of the electrode, which is not enough if the goal is to obtain a long-lifetime neural electrode.

Because of this, the main aim of the proposal is to develop a multifunctional PEDOT-based electrode for neural tissue interface. The studies will include the fabrication and investigation of PEDOT-based electrode toward its electronic and chemical neural interface. The effect of three main conditions will be examined during the fabrication process: type of the polymer synthesis (electrodeposition, drop-casting), a form of the synthesized polymer coating (solid film, hydrogel), and type of the electrode substrate (rigid, flexible). The chemical interface of the specified PEDOT electrodes will be modified by the introduction of an anti-inflammatory drug reservoir. The drug release profile of each electrode during the electrode stimulation will be examined. The stability profile of PEDOT electrodes during its stimulation will be investigated. The stability mechanism will be proposed and discussed. Biological characterization of the electrodes will be evaluated in the presence of neural human cell lines.

The studies within the proposal will allow to fabrication of multifunctional PEDOT-based electrode containing both electrical and chemical neural interface functions, whose functional electrical parameters (interfacial impedance, charge injection capacity) will be at least as efficient as currently used metallic electrodes. The optimized multifunctional PEDOT-based electrode for the neural interface will be characterized with the following parameters:

(a) Electrical interface: at least the same or lower interfacial impedance, higher charge injection capacity, higher electroactivity, higher surface area – compared to available on the market metallic rigid platinum electrodes,

(b) Chemical interface: introduction of an anti-inflammatory drug reservoir in the polymeric structure; the modulation of the chemical interface of the electrode will not affect the already optimized parameters of electrical interface; the drug will be gradually released from the polymeric during the electrode stimulation with the effectiveness of min. 90 %,

(c) Stability: electrodes with the optimized electrical and chemical interface will reveal a minimum 3-4 times longer electrode lifetime compared to currently used platinum electrodes,

(d) Biocompatibility: optimized electrodes will be characterized with high biocompatibility (low cytotoxicity) in the presence of human neural cells; effective stimulation of the human neural cell via optimized PEDOT-based electrode will be observed.